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SUBJECT Comments and Evaluation of 12 Articles on Metals, Alloys
Grain Structure and Physical Properties.

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INDEX

No.	Title	Page
1.	<u>On the Activation Energy of Superlattice Transformation.</u>	2
2.	<u>Modification of Aluminum-Germanium Alloys.</u>	2
3.	<u>X-Ray Investigation of Ordering in the Alloy AuCu.</u>	3
4.	<u>On the Question of the Expansion of Some Alloys on Solidifications</u>	3
5.	<u>X-Ray Data on the Aging of an Aluminum-Copper Alloy</u>	4
6.	<u>On the Relation of Mechanical Properties of Alloys to Their Composition and Structure.</u>	5
7.	<u>Secondary Austenitic Grain Size in Steels with Aluminum Additions</u>	6
8.	<u>Fracture Characteristics of Crystals</u>	7
9.	<u>Variation of Microhardness Values within a Single Crystalline Grain of Metal</u>	7
10.	<u>Advance of a Boundary during Change of an Aggregate Condition on Heating or Cooling Solids</u>	8
11.	<u>Effect of Concentration Gradients on the Rate of Lateral Growth of Pearlite Grains</u>	8
12.	<u>Thermal Expansion Near the Melting Point</u>	9

25X1

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1. On the Activation Energy of Superlattice Transformation. by N.S. Akulov and E.P. Svirina: Doklady Akademii Nauk SSSR 70 (1950) no. 5, pp 789/791.

A. The kinetics of short-range ordering of molybdenum permalloy (77.5% Ni, 19.5% Fe and about 3% Mo) were studied by magnetic means. The activation energy so determined was close to that reported by Barrett for permalloy based on X-ray determinations.

B. The activation energy given by Barrett seems to apply to recovery from cold work rather than to ordering, but these values are generally of the same order of magnitude. Since Akulov and Svirina refer to a Russian edition of Barrett, it is possible that the translation did not make this clear.

C S Barrett: Structure of Metals McGraw-Hill Book Co. Inc. (1943) p 250.

C. Akulov and Svirina mention that order may be detected by neutron as well as X-ray diffraction. There is no indication whether this statement is based on Soviet or foreign work. The first USA work using neutron beams from the Oak Ridge nuclear reactor to show superlattice lines for ordered FeCo and Ni₃Mn was reported in 1948.

C E Birchenall: Physical Factors Affecting Order In Metallic Systems. Thermodynamics in Physical Metallurgy. ASM (1950) pp 144/160

2. Modification of Aluminum-Germanium Alloys. By E A Boom: Izvestiya Akademii Nauk SSSR. Otdeleniye Khimicheskikh Nauk (1947) no. 3, pp 317/318 (Figures 2 to 7 With photomicrographs are missing)

A. An academic paper. The addition of small amounts of sodium to aluminum-germanium alloys causes grain refinement similar to that observed in aluminum-silicon alloys.

B. The constitution diagram as well as all three references are non-Soviet.

C. Boom has continued his work in this field since 1947 as another (unreviewed) paper of his on aluminum-germanium alloys appeared in 1952.

E A Boom: New Phases in the Aluminum-Germanium-Sodium and Aluminum-Germanium-Lithium Systems. Doklady Akademii Nauk SSSR 84 (1952) pp 697/699

D. Apparently germanium was selected merely because of its close chemical relation to silicon. There is no evidence in this paper to indicate a commercial use of aluminum-germanium alloys or any potential advantage of these alloys over the cheaper and more conventional aluminum-silicon alloys. As far as is known, germanium is not used in the USA as an alloying element for aluminum.

E. Much work has been done on the effect of sodium modification on aluminum-silicon alloys, and many hypotheses have been proposed. Boom's approach - namely - the determination of alloy systems other than aluminum-silicon where sodium modification is effective - would appear to be less promising than the alternate approach - namely, a more detailed investigation of the modification process in aluminum-silicon alloys where it is known to be effective. A procedure containing radioactive sodium tracers. While preliminary results along this line have not proved a single theory, they have served to invalidate some hypotheses and thus have probably contributed more to the theory of modification than Boom's paper, which merely shows that aluminum-germanium alloys are susceptible to modification.

AB Michael and M.B. Bever: On the Distribution of Sodium in Modified Al-Si Alloys. TMS 197 (1953) pp 679/680

CONFIDENTIAL

- 3 -

3. X-Ray Investigation of Ordering in the Alloy AuCu. By N N Buynov:
Zhurnal experimental'noy i teoreticheskoy fiziki 17 (1947) pp 41/46
 - A. A research paper to clarify certain discrepancies in the literature:
 - (1) There is a linear relation between S (degree of long-range order) and a/c (degree of tetragonality)
 - (2) The abrupt change in S (and therefore also in latent heat) near the critical temperature confirms the viewpoint that the ordering of AuCu represents a first-order transformation.
 - (3) In the equilibrium condition only one of three possible phases was observed at each temperature.
 - (4) There is no direct connection between ordering and changes in the a/c ratio, and the linear relation between S and a/c does not exist if the structure is changed.
 - B. Changes in the axial ratio of the unit cell when the ordered phases is tetragonal have long been recognized as an indicator of order. X-ray measurements are generally used as a standard, however, unless both components have nearly the same scattering factors for X-rays.

W Shockley and F C Nix: Order and Disorder in Alloys. Review of Modern Physics 10 (1938) p 1/71
 - C. Recent work by Newkirk confirms the view that the ordering of AuCu represents a first-order transformation. Newkirk, however, did find a two-phase region separating the order and disorder fields.

J B Newkirk: Order-Disorder Transformation in Cu-Au Alloys Near the Composition CuAu. TAME 197 (1953) pp 823/826
 - D. It is interesting that an English abstract is given at the end of Buynov's paper.
4. On the Question of the Expansion of Some Alloys on Solidification. By A A Bochvar, Z A Sviderskaya and E K Korbut: Izvestiya Akademii Nauk SSSR Otdeleniye Tekhnicheskikh Nauk (1947) no. 4, pp 409/417
 - A. Some alloys expand rather than shrink on solidification. Although considerable foreign work was done on this question from 1906/1930., the relation between this expansion and the constitution diagram is still unsettled. Tests were made on a series of aluminum-zinc, aluminum-magnesium, aluminum-copper and aluminum-silicon alloys as well as on various pure metals. Additional tests were made to investigate the influence of gas content and superheating.
 - (1) In alloys the maximum value of expansion was found in compositions between those with the greatest solidification range and the eutectic.
 - (2) The temperature interval during which expansion occurs corresponds to temperatures between the liquidus and the solidus.
 - (3) Tin, zinc, lead, magnesium and bismuth showed no expansion on solidification; aluminum showed a small expansion under some conditions and none under others.
 - (4) Experimental conditions have a marked effect on the degree of expansion. This factor undoubtedly explains the disagreement between the present figures and those obtained by previous investigators.
 - (5) This work proves that some alloys actually expand on solidification., but further work is needed to clarify the causes of this expansion. It is quite possible that the same explanation does not apply in all cases. For example, in one case dissolved gases may be the cause, but in others, a phase transformation.

- B. Bochvar, Sviderskaya and Korbut obviously are aware of some of the shortcomings of their work, notable among which is the failure of their tests to show an expansion for bismuth. It is well known that a number of the "low melting alloys" containing bismuth expand. The present Soviet work, however, offers little if any explanation of the phenomenon found with these alloys. For example, alloys with more than 55% Bi generally expand during solidification. But many follow the laws of thermal contraction during cooling from the solidification temperature to room temperature. Some show shrinkage for the first few minutes after solidification, and then start growing rapidly; others shrink during cooling to room temperature, and the growth does not begin for some time after the alloy has reached room temperature. Approximately 90% of the growth occurs during the first 12 to 24 hr after casting, but some low-melting alloys continue to grow at reduced rates for 500 to 1000 hr after casting. Most of these latter types of growth would probably not even have been observed by Bochvar, Sviderskaya and Korbut.
- C. The practical importance of this subject for the foundry industry is mentioned, but the work to date will probably not be much more help to the practical foundryman than to the theoretician.
- D. The aluminum-zinc constitution diagram given is about the same as that shown in the 1948 Metals Handbook (p 1167) But Bochvar, Sviderskaya and Korbut believe their results indicate the existence of a peritectic at 443 C. This peritectic had previously been reported by Hanson and Gayler in 1922, but could not be confirmed by Gayler and Sutherland in 1938. Heat effects at 443 C have not been explained convincingly.
5. X-Ray Data on the Aging of an Aluminum-Copper Alloy by Yu A Bagaryatskiy:
Doklady Akademii Nauk SSSR 77 (1951) no. 2, p. 261/264
- A. A research paper. Although the mechanism of aging has probably been more extensively studied in aluminum-copper than in any other alloys, there is still no agreement on low-temperature aging. Tests were made on a 4% Cu alloy.
- (1) Thin lamellae of the metastable theta-prime phase characteristic of high-temperature aging are not formed on low-temperature aging.
 - (2) The existence in aluminum-copper alloys after natural aging of lamellae two to three atoms thick with a high concentration of copper atoms has almost certainly been proved. These lamellae cause only slight distortion of the structure of the matrix solid solution.
 - (3) In the tempering stage corresponding to the second increase of hardness (after the regression), a superstructure in the solid solution with the structure of theta-prime phase is observed. The fields with the superstructure consist of 12 layers of atoms with the concentration of copper atoms in them corresponding to CuAl₂. At first the theta-prime nuclei are completely coherent; they then break away from the lattice and further growth proceeds with the recrystallization of the surrounding solid solution.
 - (4) A theory covering these points is proposed. In low-temperature aging, elastic energy conditions favor the segregation of copper atoms on two or three atom planes. The copper distribution is therefore very uneven, as are the stresses. At higher temperatures the role of elastic energy decreases, so a large number of copper-aluminum bonds may form; and there is a more uniform distribution of copper atoms. The regression proves that the transition from the condition characteristic of low-temperature aging to the condition for high-temperature aging cannot be continuous. Thus the factors involved in the natural aging of aluminum-copper alloys are very different from those for high-temperature aging in respect to specific atom volume of the solid solution and the precipitated phase. In aluminum-copper-magnesium and aluminum-silver alloys these differences are slight so the mechanism of aging in these latter alloys must be different.
- B. The conclusions drawn from the X-ray data, as well as the proposed theory, appear competent if not highly original.
- Age Hardening of Metals. ASM (1940)
 C.S. Barrett: Structure of Metals. McGraw-Hill Book Co., Inc. (1943)
 F. Seitz: The Physics of Metals. McGraw-Hill Book Co., Inc. (1943)

CONFIDENTIAL

-5-

Symposium on Internal Stresses in Metals and Alloys. The Institute of Metals (1948)
Relation of Properties to Microstructure. ASM (1954)

- C. Five of the 11 references are non-Soviet. It seems rather odd that there is no reference to Orowan, or to Mott and Nabarro, all of whom have been outstanding in the field of precipitation hardening from a theoretical viewpoint.

6. On the Relation of Mechanical Properties of Alloys to their Composition and Structure. A A Bochvar: Izvestiya Akademii Nauk SSSR Otdeleniye Tekhnicheskikh Nauk (1946) no. 5, pp 743/752

- A. Review and discussion of literature. The question of the relation between the properties of alloys and their composition has proved to be considerably more complicated than was earlier imagined. N S Kurnakov's proposed relation "composition - properties" is too limited. Actually the far more complex problem that should be considered is the relation "Properties - composition - structure - temperature".

- B. The main aim of this paper appears to have been a defense of a proposal made to the Academy of Sciences to include "problems of controlling the properties of alloys" in their five-year plan of investigations. In other words, it is a typical justification for research funds. Bochvar seems to have been at least moderately successful as indicated by three 1947 papers of his that have been reviewed; the first of these is exactly along the lines he talked about in the present paper.

A A Bochvar: Effect of Composition and Structure on the Elevated-Temperature Strength of Aluminum Alloys. Izvestiya Akademii Nauk SSSR (1947) no. 10, pp 1369/1384

A A Bochvar, Z A Sviderskaya and E K Korbut: On the Question of the Expansion of Some Alloys on Solidification. Izvestiya Akademii Nauk SSSR Otdeleniye Tekhnicheskikh Nauk (1947) no. 4, pp 409/417

A A Bochvar and O S Zhadaeva: Variation of Microhardness Values within a Single Crystalline Grain of Metal. Izvestiya Akademii Nauk SSSR Otdeleniye Tekhnicheskikh Nauk (1947) no. 4, pp 419/424

Presumably these three papers represent work that was started after the present 1946 paper was written.

- C. This subject is, of course, of much interest everywhere. Its present-day significance in the US is shown by the fact that the ASM held a seminar in October 1953 on the Relation of Properties to Microstructure. Bochvar's approach appears to be on the practical rather than on the theoretical side despite his emphasis on utilization of "new" research tools such as microhardness and the electron microscope. This can best be seen by comparing his work with four of the papers from the ASM seminar.

M Gensamer: The Effect of Grain Boundaries on Mechanical Properties. TASM 46A (1954) pp 16/29

E R Parker and T H Hazlett: Principles of Solution Hardening. TASM 46A (1954) pp 30/70

J E Dorn and C D Starr: Effect of Dispersions on Mechanical Properties. TASM 46A (1954) pp 71/94.

A D Schwabe: Structure and Alloy Design. TASM 46A (1954) pp 108/130

- D. There are several not-too-delicate rebukes to N S Kurnakov, particularly in regard to his ignoring the effect of temperature. The importance of this factor would naturally depend on which properties are of interest. Temperature is, of course, vital to Bochvar in view of his interest in the elevated-temperature properties of aluminum alloys.

- E. One of the illustrative examples used by Bochvar is the effect of composition on the properties of aluminum-zinc alloys, and especially the relatively low hardness of alloys with about 80% Zn. The actual constitution diagram is similar to that contained in the 1948 Metals Handbook (p 1167). A relation between the low-hardness alloys and the eutectoid at about 78% Zn and 275 C would appear to be evident, especially since some of the tests were made at 300 C; but Bochvar is apparently not satisfied with this simple answer. Details on this work (reference 7) are missing, so it is difficult to evaluate the original work.

CONFIDENTIAL

- 6 -

7. Secondary Austenitic Grain Size in Steels with Aluminum Additions. by D S Kamenetskaya and Y B Piletskaya: Zhurnal Tekhnicheskoy Fiziki 24 (1954) no. 1, pp 60/66
- A. Samples of a carbon steel with and without aluminum deoxidation were obtained by remelting a 0.43% C steel in vacuum. Estimates of the perlite-austenite transformation of these steels were made at 800 and 820 C.
- (1) Aluminum dissolved in steel promotes the nucleation of secondary austenite (on heating) but slows the growth of these nuclei. This explains the generally known fact that the addition of aluminum decreases the secondary austenitic grain size of steels.
 - (2) A theoretical consideration of these experimental results indicates that dissolved aluminum lowers boundary and surface energy and increases the energy of activation for transformation (nucleation and growth of secondary austenite).
- B. A rather interesting and unusual approach to this question but, nevertheless, a wholly unsatisfactory piece of research because of lack of basic information.
- (1) The conclusions are based on the "fact" that the unspecified amount of aluminum added to the steel is present as dissolved metallic aluminum, presumably because the steel was melted in vacuum. No details are given on the degree of vacuum, degassing and other important items of procedure. Most important of all is the lack of analyses, either for aluminum or for oxygen and nitrogen - both of which are likely to combine with aluminum if present. In other words, the authors merely surmise that all the aluminum was present in the metallic state because of their presumption that the vacuum melting removed all oxygen and nitrogen. A few analytical tests would have made this much more probable.
 - (2) No magnification is given for figures 1 to 4, which were apparently taken from a previous paper (reference 3).
 - (3) The conclusions on the rate of nucleation and growth are not completely clear in view of the experimental results given. Moreover, the incubation period has been ignored.
 - (4) This work is apparently a continuation of previous research on this subject by one or both of the authors (references 3,6 and perhaps 10 although the first initial is different for the last reference). It is possible therefore, that some of the questionable points have been answered in previous papers.
- C. The theory that metallic aluminum dissolved in the steel is responsible for the effect of aluminum additions on the grain-coarsening tendencies of steel is not new. The general opinion now, however, is that this theory has been disproved. Case and Van Horn recently summarized all the work on this subject and concluded "The most recent investigations appear to invalidate the residual - aluminum theory and assign only a secondary effect to refractory alumina particles... The majority of the evidence at the present time indicates that aluminum nitride is the most important grain inhibitor in steel."
- Case and Van Horn also point out the fallacy of the theory originally proposed by Benedicks and Lofquist that the aluminum might behave as a homophilic substance, lowering the surface tension of the grain boundaries.
- S L Case and K R Van Horn: Aluminum in Iron and Steel. John Wiley & Sons Inc. (1953)
- D. It is surprising that all ten references are Soviet since much work has been done in this field elsewhere.

CONFIDENTIAL

- 7 -

- 8: Fracture Characteristics of Crystals. N V Belov and M V Klassen-Neklyudova Zhurnal Tekhnicheskoy Fiziki 18 (1948) no. 3, pp 265/278
- A. A Crystallographic paper dealing - on the basis of literature and some original research - with cleavage planes and their relation to space lattices of metals and minerals. The examples illustrate the close connection between cleavage planes and the geometric structure of the ideal crystal lattice. Only about 15% of the paper is devoted to metals.
 - B. The subject is dealt with purely from the geometric-crystallographic viewpoint. For example, no indication is given as to possible variations in critical normal stress for brittle cleavage, nor is the effect of temperature discussed in any detail.
 - C. There seems to be nothing particularly new except perhaps the distinction that is made between "cleavage", which refers to fracture along perfect crystallographic planes, and "separation", which refers to fracture along previous twin planes or along crystallographic planes where submicroscopic particles have precipitated. In other words, separation will not occur in perfect crystals, but cleavage will.
 - D. Some of the figures are not too clear. Figure 8, for instance, does not make it clear that within each of the layers of molybdenite the atomic arrangement is hexagonal, just as shown in Figure 7 for graphite.
 - E. Four of the eight references are Soviet.
9. Variation of Microhardness Values within a Single Crystalline Grain of Metal
- A. To explain the property variations of microscopically small volumes of metal, a study was made of the microhardness of coarse-grained copper, copper zinc, solid solution alloy and aluminum.
 - (1) There was a sizeable variation in the hardness values obtained within a single coarse grain when the indentations were made in geometrically predetermined positions with no reference to microstructure.
 - (2) Microhardness tests made along the main dendritic axes within a grain showed practically no scatter, but there was still an appreciable variation in hardness values taken at random or in other crystallographic positions in the same grain.
 - (3) The large scatter of microhardness values is therefore attributable to structural nonuniformity. Consequently, the microhardness test is a satisfactory means of determining the character and degree of nonuniformity within grains of metals and alloys.
 - (4) Work is under way to improve the sensitivity of the Soviet microhardness tester used so that loads of one gram and less may be used.
 - B. The Soviet microhardness tester is not described in detail but the load used (2g) is considerably lower than the minimum load that is normally applied with the Knoop or Tukon hardness tester, the most popular microhardness tester in the US. The minimum recommended load for the latter is 25 g, and erratic results have sometimes been reported for loads under 100 g.
 L P Tarasov and N W Thibault: Determination of Knoop Hardness Numbers Independent of Load. TASM 38 (1947) pp 331/343; disc 348/353
 - C. One basic factor that Bocharov and Zhadaeva have ignored is the effect of crystallographic orientation. In addition to the large changes in hardness depending on crystallographic orientation, there is a regularity to the variation of hardness for each plane consistent with the crystal symmetry. It is generally agreed in the US that, when microhardness values determined on single crystals are quoted, the orientation should be specified; or a statement made to indicate that the hardness number is an average resulting from a large number of indentations made in random orientation. Since Bocharov and Zhadaeva

did not realize the importance of crystallographic orientation, their conclusions must be viewed with skepticism.

N W Thibault and H L Nyquist: The Measured Knoop Hardness of Hard Substances and Factors Affecting its Determination. TASM 38 (1947) pp 271/323: disc 323/330
 F W Daniels and C G Dunn: The Effect of Orientation of Knoop Hardness of Single Crystals of Zinc and Silicon Ferrite. TASM 41 (1949) pp 419/438: disc 438/442.

10. Advance of a Boundary during Change of an Aggregate Condition on Heating or Cooling Solids. By I A Charnyy: Izvestiya Akademii Nauk SSSR Otdeleniye Tekhnicheskikh Nauk (1948) no. 2, pp 187/202
 - A. A mathematical paper dealing with an approximate method of calculating a variable process by considering it as a series of mixtures of stationary states. While more accurate methods are known, this approximate method is adequately precise for practical purposes. The examples calculated:
 - (1) advance of a plane surface separating two phases with a constant temperature at the boundary;
 - (2) advance of a plane surface separating two phases with a constant coefficient of heat transfer at the boundary;
 - (3) advance of a curved surface separating two phases with a constant temperature at the boundary.
 - B. This paper appears to have nothing to do with the equations set up to analyze "zone melting".
 N W Lord: Analysis of Molten-Zone Refining. TAIME 197 (1953) pp 1531/1533
11. Effect of Concentration Stresses on the Rate of Lateral Growth of Pearlite Grains
 L N Aleksandrov and B Ya Lyubov: Doklady Akademii Nauk SSSR 74 (1950) no. 6, pp 1081/1084
 - A. A mathematical treatment of S T Konobeyevskiy's proposed explanation of the relatively high rate of decomposition of solid solutions at temperatures where the rate of normal diffusion is not high. The added diffusion is considered to result from concentration stresses caused by the nonuniform distribution of dissolved elements. The calculated rates agree fairly well with the experimental values for high-purity steel. Discrepancies found with commercial steels are attributed to the influence of elements other than carbon, which were not taken into consideration.
 - B. Several different approaches to this problem have been made in the US, and good agreement with experimental data has been claimed. It is not known whether Aleksandrov and Lyubov's calculations give better agreement than has been obtained by these other investigators.
 - (1) It is rather surprising that the work of Brandt has not been considered in view of the fact that the first of his papers appeared before, and the second at about the same time as Zener's work, which is reference 7 of the present paper. Mehl has indicated that Brandt's fundamental work, modified by Mehl's data on the variation of the diffusion coefficient with carbon concentration, gives "quite good" agreement with experimental data.
 - (2) L Onsager in a discussion at the Cornell Conference on Solid State in August 1948 proposed the use of the coefficient of diffusion of carbon in ferrite rather than in austenite. Since the former coefficient is higher, this approach seems to be promising, as has been brought out by Fischer.
 W. H. Brandt: Solution of the Diffusion Equation Applicable to the Edgewise Growth of Pearlite. J Applied Physics 18 (1945) p 139
 W. H. Brandt: Some Factors Affecting Edgewise Growth of Pearlite. TAIME 167 (1946) pp 405/417: disc 417/418
 J C Fisher: Eutectoid Decompositions. Thermodynamics in Physical Metallurgy. ASM (1950) pp 201/241
 R F Mehl: The Decomposition of Austenite by Nucleation and Growth Processes. JIST 159 (1948) pp 113/129

CONFIDENTIAL

-9-

12. Thermal Expansion Near the Melting Point. G M Bartenev: Zhurnal Fizicheskoy Khimii 23 (1949) pp 1076/1082

- A. While anomalies in physical properties near the melting point may in some cases be attributed to impurities, in other cases they are considered to be the result of "phase fluctuations" where both liquid and solid phases are present. Theoretical equations dealing with anomalies in the thermal expansion near the melting point were checked against experimental data. The agreement was better for zinc and bismuth than for cadmium and mercury. It was also possible to calculate the "melting quantum" for each of these four elements. This value, which is believed to be of considerable significance, is related to the minimum number of particles involved in the transition from the macroproperties of phases to the microproperties of individual atoms and molecules.
- B. The first objection that can be raised to the present paper is the accuracy of the experimental data.
1. The actual thermal-expansion data were taken mainly from a 1937 Soviet paper (reference 6) and a 1931 British paper (reference 8).
 2. The age of these references leaves open the question as to the purity of the metals tested and the accuracy of determination. In some cases the purity of the metals was apparently not even given: in other cases the analysis appears to have been chemical only. In any case, "pure" in 1931 or even 1937 would not necessarily be considered "pure" today. Therefore, apart from the accuracy of determination, the doubt remains that the experimental data might have been affected by impurities.
- C. Even if the experimental data are taken at face value, the reliability of the equations remains dubious, inasmuch as "corrections" were needed to bring the experimental data in agreement with the calculations.

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